

Claims

1. A method of manufacturing a plastic optical transmission medium with a radially varying refractive index, comprising:

preparing a cylindrical volume having at least two concentric cylinders of prepolymeric material, wherein at least one of said at least two concentric cylinders of prepolymeric material comprises a diffusible additive which modifies the refractive index of said at least one of said at least two concentric cylinders of prepolymeric material;

surrounding said cylindrical volume with an outer tubing, wherein the outer tubing is concentric with the cylindrical volume, wherein said outer tubing comprises a polymeric material having a higher softening point temperature than the glass transition temperatures of any of said at least two concentric cylinders of prepolymeric material;

exposing the at least two concentric cylinders of prepolymer material to energy, wherein exposing the cylindrical volume to energy increases the molecular weight of the prepolymer material of the at least two concentric cylinders of prepolymeric material so as to transform the prepolymeric material to a polymeric material and produce a cylindrical volume having at least two concentric cylinders of polymeric material;

heating the cylindrical volume surrounded by the outer tubing to a temperature which is below the softening point temperature of the outer tubing and above all of the glass transition temperatures of the at least two concentric cylinders of material, wherein such heating causes diffusion of the diffusible additive in the at least one of said at least two concentric cylinders of material, wherein such diffusion of the diffusible additive modifies the radial refractive index of said cylindrical volume.

2. The method according to claim 1, wherein preparing the cylindrical volume comprises :

providing a source of molten prepolymeric material corresponding to each of the at least two concentric cylinders, wherein the source of molten prepolymeric material corresponding to the at least one of said at least two concentric cylinders of

prepolymeric material comprising a diffusible additive comprises the corresponding diffusible additive;

extruding the source of molten prepolymeric material corresponding to each of the at least two concentric cylinder via a corresponding at least two dies.

3. The method according to claim 1,

wherein exposing the at least two concentric cylinders of prepolymeric material to energy occurs after heating the cylindrical volume surrounded by the outer tubing.

4. The method according to claim 1,

wherein exposing the at least two concentric cylinders of prepolymeric material to energy occurs before heating the cylindrical volume surrounded by the outer tubing.

5. The method according to claim 1,

wherein exposing the at least two concentric cylinders of prepolymeric material to energy occurs while heating the cylindrical volume surrounded by the outer tubing.

6. The method according to claim 1,

wherein heating the cylindrical volume occurs during at least two periods of time,

wherein at least one of the at least two periods of time is before exposing the at least two concentric cylinders of prepolymeric material to energy and at least one other of the at least two periods of time is after exposing the at least two concentric cylinders of prepolymeric material to energy.

7. The method according to claim 1,

wherein exposing the at least two concentric cylinders of prepolymeric material to energy comprises exposing the at least two concentric cylinders of prepolymeric material to heat sufficient to increase the molecular weight of the

prepolymeric material of the at least two concentric cylinders of prepolymeric material so as to transform the prepolymeric material to polymeric material.

8. The method according to claim 1,

wherein exposing the at least two concentric cylinders of prepolymeric material to energy comprises exposing the at least two concentric cylinders of prepolymeric material to one or more energy sources selected from the following group:

electromagnetic radiation, ionizing radiation, and ultra sound.

9. The method according to claim 1, further comprising :

annealing the cylindrical volume surrounded with the outer tubing.

10. The method according to claim 1, further comprising :

surrounding the cylindrical volume with a coating prior to surrounding the cylindrical volume with an outer tubing.

11. The method according to claim 10, wherein the coating comprises a polymeric material.

12. The method according to claim 1, wherein the diffusible additive is nonpolymerizing.

13. The method according to claim 1, wherein the at least two concentric cylinders of polymeric material comprise an inner cylinder of polymeric core material and an outer cylinder of polymeric cladding material.

14. The method according to claim 13, wherein the polymeric core material and the polymeric cladding material are Perfluorinated.

15. The method according to claim 13, wherein said inner cylinder of polymeric core material comprises a diffusible additive which raises the index of refraction of said inner cylinder of polymeric material.

16. The method according to claim 13, wherein the polymeric core material and the polymeric cladding material are Perfluorinated with the addition of chlorine substituents.

17. The method according to claim 13, wherein the polymeric core material and the polymeric cladding material are the same material.

18. The method according to claim 13, wherein the polymeric core material and the polymeric cladding material are different materials.

19. The method according to claim 10, wherein the at least two concentric cylinders of polymeric material comprise an inner cylinder of polymeric core material and an outer cylinder of polymeric cladding material, wherein the polymeric core material and the polymeric cladding material are partially fluorinated and the polymeric coating material is perfluorinated.

20. The method according to claim 13, wherein the polymeric core material and the polymeric cladding material are organic.

21. The method according to claim 10, wherein the at least two concentric cylinders of polymeric material of the modified cylindrical volume comprise an inner cylinder of polymeric core material and an outer cylinder of polymeric cladding material, wherein the polymeric core material and the polymeric cladding material are organic and the polymeric coating material is partially fluorinated.

22. The method according to claim 10, wherein the at least two concentric cylinders of polymeric material of the modified cylindrical volume comprise an inner cylinder of polymeric core material and an outer cylinder of polymeric cladding material, wherein the polymeric core material and the polymeric cladding material are organic and the polymeric coating material is perfluorinated.

23. The method according to claim 13, wherein the glass transition temperatures of the polymeric core material and the prepolymeric cladding material are in the range from about 108°C to about 335°C.

24. The method according to claim 13, wherein the glass transition temperatures of the polymeric core material and the polymeric cladding material are in the range from about 120°C to about 150°C.

25. The method according to claim 13, wherein the refractive indices of the polymeric core material and the polymeric cladding material are greater than about 1.31.

26. The method according to claim 13 wherein the refractive indices of the polymeric core material and the polymeric cladding material are greater than about 1.32 and less than about 1.38

27. The method according to claim 13, wherein the inner cylinder of polymeric core material comprises the diffusible additive, wherein the difference in refractive index between the polymeric core material and the diffusible additive is less than about 0.25.

28. The method according to claim 13, wherein the inner cylinder of polymeric core material comprises the diffusible additive, wherein the difference in refractive index between the polymeric core material and the diffusible additive is less than about 0.15.

29. The method according to claim 13, wherein the inner cylinder of polymeric core material comprises the diffusible additive, wherein the difference in refractive index between the polymeric core material and the diffusible additive is less than about 0.075.

30. The method according to claim 13, wherein the outer cylinder polymeric cladding material comprises the diffusible additive, wherein the difference in refractive index between the polymeric cladding material and the diffusible additive is less than about 0.25.

31. The method according to claim 13, wherein the outer cylinder of polymeric cladding material comprises the diffusible additive, wherein the difference in refractive index between the polymeric cladding material and the diffusible additive is less than about 0.15.

32. The method according to claim 13, wherein the outer cylinder of polymeric cladding material comprises the diffusible additive, wherein the difference in refractive index between the polymeric cladding material and the diffusible additive is less than about 0.075.

33. The method according to claim 11, wherein the at least two concentric cylinders of polymeric material comprise an inner cylinder of polymeric core material and an outer cylinder of polymeric cladding material, wherein the refractive index of the coating polymer material is lower than that of the outside surface of the polymeric cladding material by at least about 0.005.

34. The method according to claim 11, wherein the at least two concentric cylinders of polymeric material comprise an inner cylinder of polymeric core material and an outer cylinder of polymeric cladding material, wherein the refractive index of the coating polymer material is lower than that of the outside surface of the polymeric cladding material by at least about 0.015.

35. The method according to claim 11, wherein the at least two concentric cylinders of polymeric material comprise an inner cylinder of polymeric core material and an outer cylinder of polymeric cladding material, wherein the refractive index of the coating polymer material is lower than that of the outside surface of the polymeric cladding material by at least about 0.03.

36. The method according to claim 13, wherein during preparing the cylindrical volume the prepolymeric core material and the prepolymeric cladding material are maintained at a temperature of less than about 225°C.

37. The method according to claim 13, wherein during preparing the cylindrical volume the prepolymeric core material and the prepolymeric cladding material are maintained at a temperature of less than about 175°C.

38. The method according to claim 13, wherein during preparing the cylindrical volume the prepolymeric core material and the prepolymeric cladding material are maintained at a temperature of less than about 150°C.

39. The method according to claim 11, wherein during surrounding the cylindrical volume with a coating, the polymeric coating material is maintained at a temperature of less than about 250°C.

40. The method according to claim 1, wherein the outer tubing material retains its structural mechanical properties up to a temperature of at least about 175°C.

41. The method according to claim 1, wherein the outer tubing material retains its structural mechanical properties up to a temperature of at least about 200°C.

42. The method according to claim 11, wherein the at least two concentric cylinders of polymeric material comprise an inner cylinder of polymeric core material and an outer cylinder of polymeric cladding material, wherein the prepolymeric core material is directed to enter a die, the prepolymer cladding material, coating material, and outer tubing material enter cross-head dies within the die and a four component extrudate fiber is drawn from the die.

43. The method according to claim 1, wherein heating the cylindrical volume surrounded by the outer tubing comprises encircling the cylindrical volume surrounded by the outer tubing on a rotating drum located within a heated oven having a temperature is in the range of about 125°C to about 200°C.

44. The method according to claim 43, wherein the cylindrical volume surrounded by the outer tubing is exposed to energy within the oven.

45. The method according to claim 9, wherein annealing the cylindrical volume surrounded by the outer tube comprises encircling the cylindrical volume surrounded by the outer tubing on a rotating drum in an oven for a time period to reduce residual stress within the light transmitting polymeric material.

46. The method according to claim 9, wherein the radial temperature difference between the axis of the cylindrical volume and the outer tubing is maintained at less than about 6°C during the time the temperature of the cylindrical volume surrounded by the outer tubing falls to room temperature.

47. The method according to claim 9, wherein the radial temperature difference between the axis of the cylindrical volume and the outer tubing is maintained at less than about 3°C during the time the temperature of the cylindrical volume surrounded by the outer tubing falls to room temperature.

48. The method according to claim 45, wherein heating the cylindrical volume surrounded by the outer tube is performed in the oven.

49. The method according to claim 1, wherein the flexibility of the cylindrical volume surrounded by the outer tubing is increased by stretching the cylindrical volume surrounded by the outer tubing by a ratio between about 1.5 and about 4.0 at a minimum temperature permitted by the outer tubing material.

50. The method of claim 1, wherein the plastic optical transmission medium has an optical attenuation of less than 20 dB/km at 850 nm wavelength.

51. The method of claim 1, wherein the plastic optical transmission medium has an optical attenuation of less than 10 dB/km at 850 nm wavelength.

52. The method of claim 1, wherein the plastic optical transmission medium has an optical attenuation of less than 7 dB/km at 850 nm wavelength.

53. The method of claim 1, wherein the plastic optical transmission medium is graded-index plastic optical fiber.

54. The method of claim 1, further comprising:
jacketing the cylindrical volume surrounded by the outer tubing to produce simplex cable.

55. The method of claim 1, further comprising:
repeating the steps of preparing, surrounding, exposing, and heating to produce at least one additional cylindrical volume surrounded by a corresponding at least one additional outer tubing, wherein each repeated step is performed essentially simultaneously with the corresponding step.

56. The method of claim 55, further comprising:
jacketing the cylindrical volume surrounded by the outer tubing and one of the at least one additional cylindrical volume surrounded by a corresponding at least one additional outer tubing to produce a duplex cable.

57. The method of claim 55, further comprising:
jacketing the cylindrical volume surrounded by the outer tubing and seven of the at least one additional cylindrical volume surrounded by a corresponding at least one additional outer tubing to produce a ribbon cable.

58. The method according to claim 55, further comprising:
jacketing the cylindrical volume surrounded by the outer tubing and the at least one additional cylindrical volume surrounded by a corresponding at least one additional outer tubing to produce a multi-fiber cable.

59. A method of manufacturing a plastic optical transmission medium with a radially varying refractive index, comprising:
preparing a cylindrical volume having at least two concentric cylinders of prepolymeric material;

surrounding said cylindrical volume with an outer tubing, wherein the outer tubing is concentric with the cylindrical volume, wherein said outer tubing comprises a polymeric material having a higher softening point temperature than the glass transition temperatures of any of said at least two concentric cylinders of prepolymeric material; and

exposing the at least two concentric cylinders of prepolymer material to energy, wherein exposing the cylindrical volume to energy increases the molecular weight of the prepolymer material of the at least two concentric cylinders of prepolymeric material so as to transform the prepolymeric material to a polymeric material and produce a cylindrical volume having at least two concentric cylinders of polymeric material;

wherein the plastic optical transmission medium is a step-index plastic optical fiber.